4094 COMPUTER INTERFACING

PRELIMINARY

MP MASTER
MA29621

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GLOSSARY OF TERMS

Address	A number which represents a device attached to the GPIB or the RS-232C interface.
ASCII	American Standard Code for Information Interchange. A seven bit system of representing characters such as numbers, letters, math symbols, etc.
BASIC	A high level programming language.
Baud	Bit serial data transmission rate measured in bits per second.
Bit	A single digit in the base two numbering system. A bit is either "0" or "1". Groups of bits (8 bits = 1 byte, 4 bits = 1 nibble, 16 bits in the 4094 = 1 word) are used to encode data used in digital electronic systems.
Bit Serial	Data transmitted one bit at a time. RS-232C communications are bit serial.
Bus	Wires used to transmit groups of bits. Buses can be internal or external to a machine.
Byte	A group of eight bits.
CAMAC	The IEEE-583 interface standard. Primarily used in the nuclear industry in place of the GPIB.
Carriage Return	A computer terminal key which causes the printing head or cursor to return to the start of the line.
Carrier Freq.	A frequency which is modulated to carry binary information.
Character	Standard symbols such as: A-Z, a-z, 0-9, +, -, etc.
Controller	A device connected to an interface which commands other devices on the interface.

Data Set	See Modem.
Delimiter	ASCII character(s) used to separate or end strings of characters which belong together as a group. Carriage Return (CR) and Linefeed (LF) are common examples.
DIP	Dual In-line Package. Standard physical structure of integrated circuits. Two rows of pins are attached to the IC body.
EIA	Electronic Industries Association
Echo Check	A transmission error detection procedure in which the receiving device repeats everything back to the sender for verification. Used on RS-232C interfacing.
End of File (EOF)	A delimiter which indicates the end of a data transmission.
FORTRAN	A high level programming language.
FSK	Frequency Shift Keying. Each binary state, 1 or 0, is represented with a single frequency. These two tones are transmitted over telephone lines in standard RS-232C communications. See Carrier, Modem.
Full Duplex	RS-232C communications which can take place in two directions simultaneously.
GPIB	General Purpose Interface Bus. Specified by IEEE-488.
HPIB	Hewlett Packard Interface Bus. Essentially the same as the GPIB/IEEE-488. Devices with the HPIB are compatible with the GPIB.
Half Duplex	RS-232C communications which pass in only one direction at any given time.

Handshaking	The process of synchronizing communications between devices. A system of questions (Ready?) and replies (Yes) are used to make sure sender and receiver are properly prepared.
IEEE	Institute of Electronic and Electrical Engineers
IEEE-488	The IEEE specification for the GPIB.
I/O	Input/Output
Interface	The circuitry and programming necessary for the interconnection of electronic devices.
LSB	Least Significant Bit. In most cases the LSB is a bit representing 2^0 or 1.
Linefeed	A computer terminal key which causes the paper or cursor to advance one line.
Local Echo	The process of sending characters typed on a computer terminal keyboard to the computer terminal screen for display.
MSB	Most Significant Bit. The bit in the highest binary location in a binary number.
Modem	Modulator-demodulator. An RS-232C device used to transmit and receive binary data on telephone lines. Each binary "1" or "0" is represented with a specific signal frequency.
Noise	Unwanted signals. Interface noise is usually caused by noisy telephone lines or radio frequency interference on connecting cables.
Negative Logic	A low voltage represents a binary "1". This is the convention used by the GPIB and RS-232C data

transmission lines.

Octal — Base eight number system.

Parity Bit — A parity bit is an extra bit added to a binary word to create an even or odd number of binary bits equal to "1". By counting the number of 1's in a word and knowing whether the total should be even or odd, the receiving device can detect most errors due to interface noise. Used with RS-232C interfacing.

Positive Logic — A high voltage represents a binary "1". This is the convention used by RS-232C handshaking lines.

RS-232C — Recommended Standard 232C. An EIA specification which defines bit serial data communications.

Record Separator — A delimiter which separates data values in a transmission.

Serial Data — See Bit Serial.

Simplex — Similar to half duplex communications except that communications can travel only in one direction. It is impossible to transmit anything back to the sender.

Start Bit — A bit which precedes the eight bits (7 bits plus parity bit) representing an ASCII character. The start bit is a warning to the receiver that data will follow immediately. Start bits are at logic "0". Start bits are used with RS-232C communications.

Stop Bit — The bit(s) which immediately follow the eight bits (7 bits plus parity bit) which compose an ASCII character. The stop bits (1 or 2) define the minimum spacing between characters. Stop bits are at logic "1". Stop

bits are used with RS-232C communications.

Word — A group of bits of arbitrary length which form a single binary value. 4094 words are 16 bits long.

ASCII Code Chart

BITS 2^3 2^2 2^1 2^0	2^6 2^5 2^4 = 0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
0 0 0 0	NUL	DLE	space	0	@	P	`	p
0 0 0 1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0	STX	DC2	"	2	B	R	b	r
0 0 1 1	ETX	DC3	#	3	C	S	c	s
0 1 0 0	EOT	DC4	$	4	D	T	d	t
0 1 0 1	ENQ	NAK	%	5	E	U	e	u
0 1 1 0	ACK	SYN	&	6	F	V	f	v
0 1 1 1	BEL	ETB	'	7	G	W	g	w
1 0 0 0	BS	CAN	(	8	H	X	h	x
1 0 0 1	HT	EM	)	9	I	Y	i	y
1 0 1 0	LF	SUB	*	:	J	Z	j	z
1 0 1 1	VT	ESC	+	;	K	[	k	{
1 1 0 0	FF	FS	,	<	L	\	l	|
1 1 0 1	CR	GS	-	=	M	]	m	}
1 1 1 0	SO	RS	.	>	N	^	n	~
1 1 1 1	SI	US	/	?	O	_	o	delete

ASCII CODE CHART TRANSLATION INTO 4094 DISPLAY CHARACTERS

BITS 2^3	2^2	2^1	2^0	2^6=0 2^5=0 2^4=0	2^6=0 2^5=0 2^4=1	2^6=0 2^5=1 2^4=0	2^6=0 2^5=1 2^4=1	2^6=1 2^5=0 2^4=0	2^6=1 2^5=0 2^4=1	2^6=1 2^5=1 2^4=0	2^6=1 2^5=1 2^4=1
0	0	0	0	@	P	space	0	@	P	space	0
0	0	0	1	A	Q	!	1	A	Q	!	1
0	0	1	0	B	R	"	2	B	R	"	2
0	0	1	1	C	S	#	3	C	S	#	3
0	1	0	0	D	T	$	4	D	T	$	4
0	1	0	1	E	U	%	5	E	U	%	5
0	1	1	0	F	V	&	6	F	V	&	6
0	1	1	1	G	W	'	7	G	W	'	7
1	0	0	0	H	X	(	8	H	X	(	8
1	0	0	1	I	Y	)	9	I	Y	)	9
1	0	1	0	J	Z	*	:	J	Z	*	:
1	0	1	1	K	k	+	;	K	k	+	;
1	1	0	0	L	m	,	<	L	m	,	<
1	1	0	1	M	u	-	=	M	u	-	=
1	1	1	0	N	n	.	>	N	n	.	>
1	1	1	1	O	p	/	?	O	p	/	?

The 4094 display shows non-printable ASCII characters as underlined characters (for example, CR=M). Lower case alphabet characters and several other miscellaneous characters also undergo a translation in order to be displayed on the 4094. It is important to note that these translations are for the visual display only. The correct, unmodified 7 bit ASCII code is contained in the 4094 memory and can be sent out if requested.

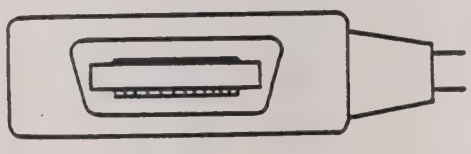
To erase displayed characters, turn the FUNCTION switch to

PRGM and then away from PRGM.

GENERAL OVERVIEW - IEEE-488/GPIB

The General Purpose Interface Bus (GPIB) has been widely accepted since April, 1975 when IEEE-488 was published. The GPIB offers interface compatibility which was previously unavailable. Since 1975, thousands of GPIB compatible products have been introduced on the market.

Figure 1 shows the layout of the standard GPIB cable and connector.



D8 pin 16	(MSB)
D7 pin 15	
D6 pin 14	Bidirectional
D5 pin 13	Data Lines
D4 pin 4	
D3 pin 3	
D2 pin 2	
D1 pin 1	(LSB)
NDAC pin 8	Data Transfer
NRFD pin 7	Control Lines
DAV pin 6	(Handshaking Lines)
ATN pin 11	
IFC pin 9	General Control
SRQ pin 10	Lines
REN pin 17	
EOI pin 5	

Pins 12, 18, 19, 20, 21, 22, 23, 24 at ground potential.

Figure 1

Physical limitations

1. No more than 15 devices on one GPIB.
2. No more than 2 meters of cable between any two devices or more than 20 meters of cable in total, whichever is less.
3. Maximum data transfer rates are set by the slowest device involved in the data transfer. Computer program execution speed is an important factor in data transfer rates.

GPIB Pin Explanations as they relate to the Nicolet 4094

D1 through D8	Carry data into or out of the 4094. Carry addresses into the 4094. Carry specialized controller commands into the 4094.
NDAC - Not Data Accepted	When "1": device ready to accept data.
NRFD - Not Ready For Data	When "1": not OK to send data.
DAV - Data Valid	When "1": data valid on data lines.
ATN - Attention	When "0": data lines have data. When "1": data lines have address or GPIB command.
IFC - Interface Clear	When "1": "clears" all devices attached to the GPIB so that they are off the GPIB.
SRQ - Service Request	When "1": tells the controlling computer that some device on the GPIB has information to be released. Not supported in the 4094.
REN - Remote Enable	When "1": all devices on the GPIB will ignore their front panel controls and operate strictly under GPIB control. Not supported in the 4094.
EOI - End Or Identify	When "1": indicates to the device receiving information that the last information to be transmitted is on the data lines. Not supported in the 4094.

"1" is represented by a low voltage (approx. 0V).

"0" is represented by a high voltage (apporx. 3V).

IEEE-488/GPIB Operation

The 4094 GPIB connector is located on the back panel of the Model 4094-2 oscilloscope. The RS-232/GPIB switch must be switched to GPIB before transfers can take place. The RS-232/GPIB switch also performs an added useful function. Each time the switch is moved the I/O processor internal to the 4094 (controlling interfaces, disk recorders, digital plotter, and disk programs) is reset. Data stored in the 4094 memory is not lost in this process. This simple resetting action can prove very useful when computer programs are being debugged. A computer reset and a 4094 reset will manually return both pieces of equipment to their start-up conditions.

The 4094 GPIB is also capable of performing bidirectional transmissions with the RS-232C plotter port. This means that a controlling computer can input to the 4094 on the GPIB and have that transmission be outputted on the RS-232C plotter interface. The GPIB interface will not be permitted to run faster (through normal handshaking procedures) than the plotter port can transfer information. However, in the reverse direction, the GPIB must keep up with information coming from the plotter port. This will not strain most GPIB controllers since this only amounts to a data transfer rate of 2000 bytes/sec. Interconnection of the GPIB and the RS-232 plotter port is covered in detail in the Advanced Interfacing Section under J command.

IEEE-488/GPIB "Clear" Commands

The three commands listed below allow the programmer to "clear" the bus of one or all addressed devices. These can be used in addition to the standard untalk, unlisten addresses shown on Table 1. The actual computer statement used to send out each "clear" command should be listed in the computer manual.

1. Interface Clear - See the GPIB line explanations. This command clears off all devices addressed on the GPIB and each device returns to its initial, unaddressed state. Computer statements such as "INIT' in BASIC are used to turn on Interface Clear.
2. Device Clear (DCL) - This command removes all devices which support Device Clear from the GPIB and returns them to their unaddressed state. In ASCII, DCL is represented by "DC4". This command is not addressed to specific devices.
3. Selected Device Clear (SDC) - Similar to Device Clear except that it affects only the devices addressed by the command. In ASCII, SDC is represented by "EOT".

Addressing

Each device connected to the GPIB must be assigned an address (decimal number) so that it can be distinguished from other devices also on the GPIB. Each address can be subdivided into a "talk" address for outputting data and a "listen" address for inputting data. The 4094 GPIB address is set via a five segment DIP switch located on the large circuit board visible when the 4094 right side cover is removed. Table 1 ties together DIP switch setting, GPIB address, listen address, and talk address.

Many computers will simplify programming by allowing the programmer to refer to a single GPIB address. The computer will correctly translate this into a talk or listen address depending on the program statement. A "PRINT" statement in BASIC infers that a listen address is required. An "INPUT" statement in BASIC would indicate that a talk address is needed. The programs shown at the end of this interfacing section show practical examples.

Table 1 equates the DIP switch setting to the GPIB address and also to the corresponding talk and listen addresses. These may have to be used if the computer does not automatically convert addresses. Consult your computer manual to find out if talk and listen addresses must be specified. Note that talk and listen addresses are expressed in decimal numbers and their ASCII character equivalents. These represent binary numbers which are derived from the DIP switch address setting by turning on bit 6 or 7 in addition to the five bits already shown on the switch. A DIP switch OFF (i.e. "OPEN") represents a binary 1. Switch 1 is the most significant bit. Example: binary 00001 = decimal 1, add bit 6 = 1; binary 100001 = decimal 33 =! in ASCII.

Unlisten and untalk addresses cause all devices on the GPIB to be removed as a listener or a talker.

Note 1: Turn Oscilloscope Off Before Setting DIP Switch

Note 2: A Switch Set to OPEN is OFF

DIP SWITCH					GPIB ADDRESS		LISTEN ADDRESS		TALK ADDRESS	
(1)	(2)	(3)	(4)	(5)	Decimal	Octal	Decimal	ASCII	Decimal	ASCII
ON	ON	ON	ON	ON	0	0	32	space	64	@
ON	ON	ON	ON	OFF	1	1	33	!	65	A
ON	ON	ON	OFF	ON	2	2	34	"	66	B
ON	ON	ON	OFF	OFF	3	3	35	#	67	C
ON	ON	OFF	ON	ON	4	4	36	$	68	D
ON	ON	OFF	ON	OFF	5	5	37	%	69	E
ON	ON	OFF	OFF	ON	6	6	38	&	70	F
ON	ON	OFF	OFF	OFF	7	7	39	'	71	G
ON	OFF	ON	ON	ON	8	10	40	(	72	H
ON	OFF	ON	ON	OFF	9	11	41	)	73	I
ON	OFF	ON	OFF	ON	10	12	42	*	74	J
ON	OFF	ON	OFF	OFF	11	13	43	+	75	K
ON	OFF	OFF	ON	ON	12	14	44	,	76	L
ON	OFF	OFF	ON	OFF	13	15	45	-	77	M
ON	OFF	OFF	OFF	ON	14	16	46	.	78	N
ON	OFF	OFF	OFF	OFF	15	17	47	/	79	O
OFF	ON	ON	ON	ON	16	20	48	0	80	P
OFF	ON	ON	ON	OFF	17	21	49	1	81	Q
OFF	ON	ON	OFF	ON	18	22	50	2	82	R
OFF	ON	ON	OFF	OFF	19	23	51	3	83	S
OFF	ON	OFF	ON	ON	20	24	52	4	84	T
OFF	ON	OFF	ON	OFF	21	25	53	5	85	U
OFF	ON	OFF	OFF	ON	22	26	54	6	86	V
OFF	ON	OFF	OFF	OFF	23	27	55	7	87	W
OFF	OFF	ON	ON	ON	24	30	56	8	88	X
OFF	OFF	ON	ON	OFF	25	31	57	9	89	Y
OFF	OFF	ON	OFF	ON	26	32	58	:	90	Z
OFF	OFF	ON	OFF	OFF	27	33	59	;	91	[
OFF	OFF	OFF	ON	ON	28	34	60	<	92	\
OFF	OFF	OFF	ON	OFF	29	35	61	=	93	]
OFF	OFF	OFF	OFF	ON	30	36	62	>	94	^
OFF	OFF	OFF	OFF	OFF	Do Not Use		Do Not Use		Do Not Use	
Unlisten/Untalk							63	?	95	_

Table 1

IEEE-488 Function Subsets

SH1	Source Handshake - complete capability
AH1	Acceptor Handshake - complete capability
T8	Basic talker & Unaddress if MLA
L4	Basic Listener & Unaddress if MTA
SRØ	Service Request - no capability
RLØ	Remote Local - no capability
PPØ	Parallel Poll - no capability
DC1	Device Clear - complete capability
DTØ	Device Trigger - no capability
CØ	Controller - no capability

GENERAL OVERVIEW - RS-232C

The Electronic Industries Association (EIA) Recommended Standard 232C has become the accepted bit-serial data transmission specification. Bit-serial interfacing was primarily developed for long distance communications over telephone lines. Widespread acceptance of RS-232C has prompted its use in non-telephone data transmissions as well. Figure 1 shows the layout of the standard RS-232C cable and connector.

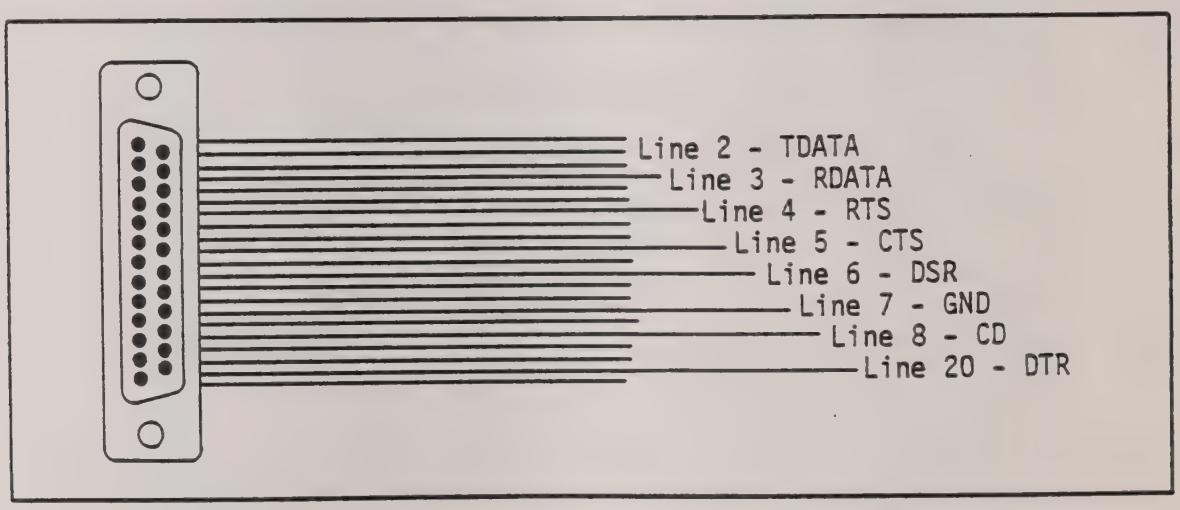


Figure 1

Physical Limitations

1. The maximum transmission distance is unlimited if telephone lines are utilized. Direct cable link-ups are limited to 50 feet.
2. The maximum data transfer rate is set by the allowable baud rates (bits per second) of the communicating devices. The Nicolet 4094 can run at 110 to 19200 baud.

RS-232C lines as they relate to the Nicolet 4094. Lines not discussed are not supported by the 4094.

#1 Protective Ground

#2 TDATA - Transmitted Data — Path for outgoing data.

#3 RDATA - Received Data — Path for incoming data.

#4 RTS - Request to Send — Activated by the sending device to tell the sending modem to get ready for data transmissions.

#5 CTS - Clear to Send — Activated by the sending modem to tell the sending device that it is ready for transmissions. The 4094 will pause during data transmission if this line is turned OFF (-10V). Data transmissions from the 4094 will resume as soon as this line is turned ON (+10V). No characters will be lost.

#6 DSR - Data Set Ready — A data set is a modem. This line is activated by the sending modem to tell the sending device that it is ready for a Request to Send.

#7 Signal Ground

#8 CD - Carrier Detected — Activated by the receiving modem to tell the receiving device that a carrier signal has been detected and data will soon follow.

#20 DTR - Data Terminal Ready Activated by the sending device to tell the sending modem that it is ready to transmit data.

Voltage	Status (for handshaking lines)	Binary (for data)
-3 volts to -25 volts	OFF	1
+3 volts to +25 volts	ON	0

Start-up Procedure

Several manual switch settings must be made before the 4094, RS-232C interface can be put into service. These settings are used to select baud rate, parity, and number of stop bits. The 4094 interface must have settings which match the connected device specifications. Factory settings are as follows:

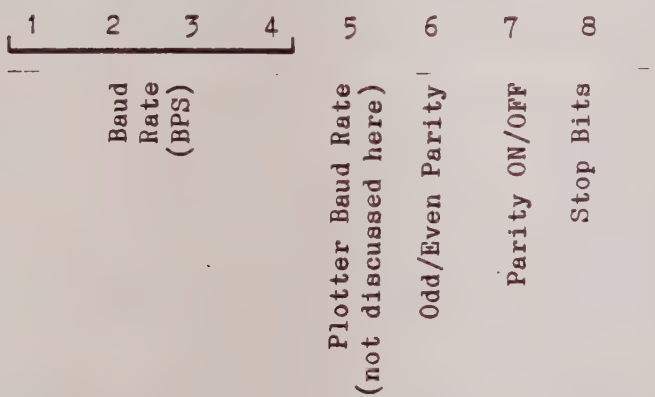
a) 300 baud

b) no parity check

c) one stop bit

The above settings may be changed with the 8 segment DIP switch located on the large circuit board visible when the 4094 right side cover is removed. After turning the oscilloscope OFF, remove the right side cover and use the following information to set the switch.

RS-232C Switch



NOTE: A switch set to OPEN is OFF.

1. Set the baud rate (bits per second) to match the baud rate of the connected device.

Baud Rate	Switch			
	1	2	3	4
300	ON	ON	ON	ON
1200	ON	ON	ON	OFF
9600	ON	ON	OFF	ON
110	ON	ON	OFF	OFF
150	ON	OFF	ON	ON
450	ON	OFF	ON	OFF
600	ON	OFF	OFF	ON
1800	ON	OFF	OFF	OFF
2000	OFF	ON	ON	ON
2400	OFF	ON	ON	OFF
3600	OFF	ON	OFF	ON
4800	OFF	ON	OFF	OFF
7200	OFF	OFF	ON	ON
14400	OFF	OFF	ON	OFF
19200	OFF	OFF	OFF	ON

2. Set the parity. The parity bit is an eighth bit sent with each group of seven bits (each ASCII character). By checking parity bits the receiving device can determine when transmission errors have occurred. If parity is turned off, parity bit checking will not be done. Transmissions from the 4094 will have the parity bit set at "0" if parity is turned off. With parity off, the 4094 will accept a parity bit "1" or "0".

Switch 6 (only used if switch 7 is OFF)

OFF - Odd parity.

ON - Even parity.

Switch 7

OFF - Parity checking turned on.

ON - Parity checking turned off.

3. Set the number of stop bits. Each ASCII character (seven bits plus a parity bit) transmitted is preceded by a start bit and followed by one or two stop bits. Communicating devices must agree on the number of stop bits to be used.

Switch 8

OFF - Two stop bits.

ON - One stop bit.

After setting switches 1 through 8 the side cover should be put back in place.

4. The 4094 RS-232C interface should be switched ON LINE if it is expected to participate in any communications. The ON LINE switch controls pin 20 (DTR) on the MODEM/COMPUTER connector, the TERMINAL connector is unaffected by this switch.

The RS-232/GPIB switch must be switched to RS-232 before transfers can take place. The RS-232/GPIB switch also performs an added useful function. Each time the switch is moved the I/O processor internal to the 4094 (controlling interfaces, disk recorders, digital plotter, and disk programs) is reset. Data stored in the 4094 memory is not lost in this process. This simple resetting action can prove useful when computer programs are being debugged. A computer reset and a 4094 reset will manually return both pieces of equipment to their start-up conditions.

5. The RS-232C connectors on the back of the 4094 are standard 25 pin, D subminiature rectangular connectors (such as Cannon DB-25S, DB-25P,

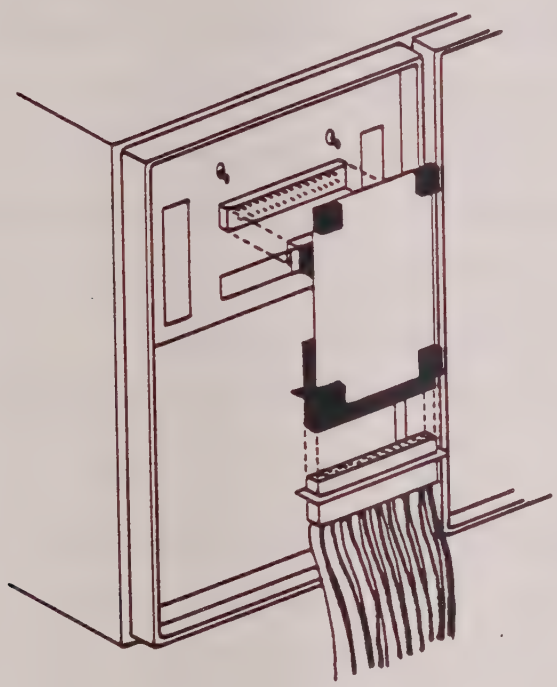
DBSP-25S, and DBSP-25P). The MODEM/COMPUTER connector is the input/output port for the 4094. The TERMINAL connector allows both the 4094 and a computer terminal to communicate with a computer connected to the MODEM/COMPUTER port. Commands sent to the TERMINAL connector will not directly control the 4094. Any device expected to input to the 4094, or receive data from the 4094, must be connected to the MODEM/COMPUTER port. The MODEM/COMPUTER port is designed to transmit and receive to/from modems and computer input/output ports configured for use with terminals. Direct connection of the MODEM/COMPUTER port to computer terminals, teletypes, and non-terminal configured computer ports will necessitate use of the Nicolet null modem printed circuit board supplied with the 4094. The null modem board is attached to the 4094 as shown in Figure 2. The null modem board provides the following:

a. Cross-connections of the transmit and receive lines.

b. Access to control lines so that specialized handshaking can be patched in if desired. For example, a computer which can control its Request To Send (RTS) line could control the 4094 data output. The computer's RTS could be patched together with the 4094 Clear to Send (CTS). When the computer RTS turns the 4094 CTS line OFF (-3 to -25 volts) the 4094 data transmission will cease. Transmissions will resume as soon as the 4094 CTS line is turned ON (+3 to +25 volts). It should be noted that this can also be accomplished by using the commands XON, XOFF if supported by the controlling computer.

c. Access to all 4094 supported RS-232C lines for test purposes.

d. Interconnection of handshaking lines so that each device will "think" that it is connected to a modem providing standard handshaking functions.



Null Modem Connection

Figure 2

RS-232C Control Characters

The RS-232C control characters are ASCII characters which initiate RS-232C transmissions, abort 4094 input transmissions, and address multiple 4094 oscilloscopes. Command C (at end of Basic Interfacing Commands section) shows how to change all default RS-232C control characters to different characters. The explanations below use the default control characters in all examples.

1. Activate RS-232C Transmissions: Two ASCII characters are required to activate the 4094 RS-232 interface (the MODEM/COMPUTER port). Before further RS-232C communications can take place these two characters must be transmitted to the 4094.

   Character 1 - SOH (CNTL A, two keys pressed simultaneously)

   Character 2 - RS-232C address (see chart)

The RS-232C address gives the unique possibility of being able to attach multiple 4094 oscilloscopes on a single RS-232C interface. The first 4094 is connected to the computer via its MODEM/COMPUTER port. The next 4094 MODEM/COMPUTER port is connected to the first 4094 TERMINAL port, and so on. This also gives the ability to connect one additional RS-232C compatible device to the last 4094 TERMINAL port if an actual terminal is not being used. The RS-232C address is a character which is equated in the chart below to the GPIB address setting (see page 16). The C command described under Basic Interfacing Commands allows the RS-232C address to deviate from the DIP switch setting.

Example: SOH> activates the RS-232C interface addressed at 14.

DIP Switch Setting	RS-232C Address Character
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	:
11	;
12	<
13	=
14	>
15	?
16	@
17	A
18	B
19	C
20	D
21	E
22	F
23	G
24	H
25	I
26	J
27	K
28	L
29	M
30	N

See the Q command for general deactivation of the RS-232C interface.

2. Pause during RS-232C Transmission: Many large computers which service many users at one time must be able to hold back low priority transmissions if high priority demands arise. This is accomplished by use of XON, XOFF control characters. The 4094 default XON, XOFF characters are "DC1" and "DC3". Command C allows these characters to be changed to any ASCII character.

Upon receipt of the XOFF character the 4094 will cease its transmission after completion of the character in process. The XON character will cause the 4094 to resume the RS-232C

transmission at the point it left off. It should be noted that the XON, XOFF characters will be seen on the 4094 display. DC1 will appear as Q DC3 will appear as S.

3. Abort input transmissions to the 4094: RS-232C transmissions to the 4094 can be aborted by use of the ASCII abort character. The default abort character is "z". The abort character can be changed by use of the C command. Use of the abort character will result in a transmission error code 21 which says that the transmission was aborted. See the Q command for general deactivation of the RS-232C interface.

BASIC INTERFACING COMMANDS

Included in the basic interfacing section are commands to:

1. Output descriptive waveform information
2. Input/output data
3. Input/output normalization
4. Store/Recall/Unprotect/Autocycle on disk recorder
5. Acquire new waveforms; run LIVE/HOLD NEXT/Abort sweep
6. Output status
7. Input/output titles
8. Change delimiters, control characters, and other optional characters
9. Make 4094 output audio "beep"

All commands are sent to the 4094 in the form of ASCII characters. A series of ASCII characters is referred to as a "character string". Computer programming manuals will have information on the correct format for statements utilizing character strings.

Every command sent to the 4094 will generate an error code number in response. The error code number must be accepted by the computer before any additional interface transfers with the 4094 can take place.

All optional delimiters are shown in their correct locations. Even though in many situations delimiters are not used, it is necessary to know what options are available. Delimiters are covered in detail under the C command.

Input/Output Data

Command Format:

W

Purpose:

The W command is used to determine the number and length of waveforms in the 4094 memory, the corresponding normalization sets, corresponding titles, input channel used, and whether retain reference was switched on. All waveforms in memory will be included, not just displayed data. This command is not manditory for data transfer (D command) but is very useful in most practical programming examples. The explanations for the D and N commands cover the uses of the waveform specifications.

Transmission Sequence:

[4094 input]

1. W Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

[4094 output]

3. Total number of waveforms (01-32) Optional record sep., EOF

[4094 output]

4. a. Waveform number (01-32) Optional record sep.

   b. Number of data points (+00496 to +15872) Optional record sep.

      (Note: spaces can be used interchangably with + signs and leading zeros)

   c. Normalizing set number (00-31) Optional record sep.

   d. Normalizing step (01-32) Optional record sep.

   e. Channel number (see Table 1) Optional record sep.

f. Retain reference (1 = RR on, 0 = RR off) Optional record sep.

g. Title number (see Table 2) Optional record sep.

h. Optional End of File (EOF) delimiter

[4094 output]

5. Error code (00-31) Optional error delimiter

Channel No.	Input Location
0	Plug-in 1, Channel A
1	Plug-in 1, Channel B
2	Plug-in 2, Channel A
3	Plug-in 2, Channel B

Table 1

Title No.	Where Title is Visible
1	Q1, H1, or ALL
2	Q2 or H2
3	Q3 or H1
4	Q4 or H2

Table 2

Command Format:

D, Mode, Waveform No., Starting Pt., Total Pts, Step

(any non-numeric character can be used to separate numeric values)

Purpose: Initiate data transfers and specify data parameters and format.

Specifications:

1.

Mode	Data Format
0	output in ASCII (optional Record Separator, optional EOF)
2	output in printable binary (optional EOF)
4	output in binary (no Rcd.Sep. or EOF)
1	input in ASCII (optional Rcd.Sep., optional EOF)
3	input in printable binary (optional EOF)
5	input in binary (No Rcd.Sep. or EOF)

2. Waveform Number - see W command. Use of Waveform Number = 0 will access all of memory rather than individual waveforms.
3. Starting pt. - The first data point on the waveform which is to be transferred (0-15871)
4. Total pts. - The total number of data points to be transferred from the waveform (1-15872). If Total Pts. is set to 0 the 4094 will force it to 1.
5. Step - Count spacing between data point numbers. A step of 2 means that every other data point will be transferred.

Transmission Sequence:

[4094 input]

1. D, Mode, Waveform Number, Starting Point, Total Points, Step Optional command delimiter.

[4094 output]

2. Error code for command (00-31) Optional error delimiter.

[4094 input or output]

3. Data values (see formats below) Optional record sep. between values.

   (Note: I/O of standard binary data values cannot include record sep. delimiters)

[4094 input or output]

4. Optional End of File (EOF).

   (Note: I/O of standard binary data values cannot include EOF delimiters)

[4094 output]

5. Error code for data transmission (00-31) Optional error delimiter.

Data Format:

Data point values range from -32768 to +32767 regardless of input voltage range, voltage offset, or any other front panel setting. To translate each data point value into the correct voltage, normalizing information is required (see the N command). Data point values can be input/output in 3 possible formats. Each format is discussed below.

1. ASCII Data Values

   Six ASCII characters transferred for each data point.

   Examples: -16421 or +00125

   (a space may be used interchangeably with + signs and leading zeros)

   Advantages:

   a. Usually easiest to program in computer; translations from ASCII characters into computer integers is usually unnecessary.

b. Compatible with RS-232C interface equipment.

Disadvantages:

a. Slow data transfer due to the large number of characters transferred.

b. Large computer memory required if brought in as a long ASCII character string.

(15872 data pts. x 6 characters/data pt. = 95232 bytes.

2. Printable Binary Data Values

Three ASCII characters are transferred for each data point. The three characters need to be correctly converted into standard binary form and combined before they can be treated as a single numeric value by the computer. The ASCII characters are transmitted in their order of numeric significance. Likewise, data to be sent from a computer to the 4094 must undergo a conversion into printable binary if Mode 3 is selected. The conversion scheme to transform printable binary into standard binary is given below.

a. Convert the printable ASCII characters (printable binary) into their binary equivalents. See the ASCII chart on page 8. Ignore parity bits (bit 2^7) included during transmission.

Data Point 1 = $')

Data Point 2 = /U^

$ = 0100100	/ = 0101111
' = 0100111	U = 1010101
) = 0101001	^ = 1011110

b. Subtract 32 (0100000) from each binary number. Thirty-two was added to the original data to bring it into the range of

printable ASCII characters.

```
$ 0100100          / 0101111
- 0100000          - 0100000
  0000100            0001111

' 0100111          U 1010101
- 0100000          - 0100000
  0000111            0110101

) 0101001          ^1011110
 -0100000          -0100000
  0001001            0111110
```

c. Multiply the most significant number by 4096, the next most significant by 64, and add up all three. This operation sets each number to the correct binary significance and combines them to form one value.

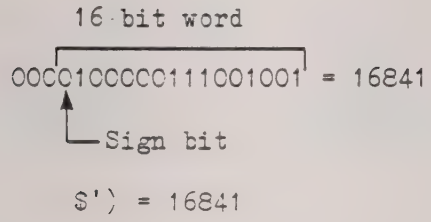
(0000100)(4096) + (0000111)(64) + (0001001) = 0000100000111001001

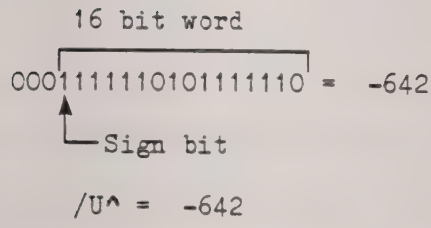
(0001111)(4096) + (0110101)(64) + (0111110) = 0001111110101111110

d. Each 4094 data word is a sixteen bit, 2's compliment word. Bit 16 of the word resulting from part c indicates the correct sign (1 = negative no., 0 = positive no.).

Note that bits 17, 18, and 19 resulting from part c will always be 0 and are meaningless. Word lengths in computers vary considerably and therefore it is necessary to ensure that the sign bit is repeated to the necessary number of places. The easiest way to do this is to subtract 65536 if the result from part c is greater than or equal to 32768. This action

effectively extends the sign bit out to the necessary number of places.





Sign bit extension for computer with 20 bit words.

```
  00011111101011111110
+11110000000000000000  add -65536
(11111111110101111110) =    -642
        20 bit word
```

Advantages:

a. Faster than straight ASCII data due to fewer transmitted characters.

b. Compatible with RS-232C equipment.

Disadvantages:

a. Added programming necessary to translate ASCII characters into binary or binary into ASCII characters.

b. Slower than standard binary transmissions due to greater number of transfers.

3. Standard Binary Data Values

Each data point is transmitted as two 8 bit bytes. The high byte (places 2^{15} through 2^{8}) is transferred first followed by the low byte (places 2^{7} through 2^{0}). Each high byte/low byte pair must be combined in order to form a single binary value. Likewise, binary data sent into the 4094 must be transformed into high and low bytes for transmission. A scheme to combine high and low bytes is given below.

a. Multiply the high byte by decimal 256 and add the result to the low byte. This operation sets the high byte to the correct binary significance and combines the high and low bytes. The resulting binary number is a standard 16 bit 2's compliment representation of a single data point.

b. Since standard computer word lengths vary considerably it should be noted that it may be necessary to extend the sign bit (bit 2^{15}) to fill the remaining bit positions. This can be done in one of two ways:

i. Check the value of bit 2^{15} and set the remaining unspecified bits to equal bit 2^{15}.

Example: Computer word length=20 bits

```
    1111111100010110 = data from 4094
    ↑
bit 2^15

<---- extend sign bits

11111111111100010110
20-bit word
```

ii. Check the value of 16 bit number and if greater than or equal to 32768 subtract decimal 65536(2^{16}). This effectively extends the sign bits out to the most significant place.

Example: Computer word length = 20 bits.

```
    1111111100010110 = data from 4094
+11110000000000000000 add -65536
11111111111100010110
20-bit word
```

Advantages:

a. Fastest possible data transmission rate due to minimum number of transfers.

b. Extra translations are unnecessary, a simple procedure combines high and low bytes.

Disadvantages:

a. Not commonly compatible with RS-232C equipment.

b. Binary transmissions on the GPIB may require different I/O commands inside the computer than those used for ASCII transfers. Sometimes talk and listen addresses must be

given (review GPIB addressing page 15).

Input/Output Normalization Data

Command Format:

To output from 4094: N, Norm. Set no.

To input to 4094: N, Norm. Set no., Norm. Step

(any non-numeric character can be used to separate numeric values)

Purpose:

Initiate transfer of normalization data necessary to convert data point values into time and voltage measurements.

Specifications:

1. Norm. Set No. - The number of the normalization set to be transferred. The normalization set number which corresponds to a given waveform results from use of the W command.
2. Norm. Step - A number which allows the 4094 to place a given normalization set into the correct memory locations. The normalization step must be given to the 4094 before normalization sets are sent to the 4094. This number only has importance for internal 4094 operation. The W command will give the normalization step number for each normalization set.

Transmission Sequence:

[4094 input]

1. N, Norm. Set No., (Norm. Step required to send normalization to the 4094) Optional command delimiter.

[4094 output]

2. Error code for command (00-31) Optional error delimiter.

[4094 input or output]

3. a. Waveform validity (see Table 3) Optional record sep.

b. Sweep size index (see Table 4) Optional record sep.

c. Channel no. (see Table 5) Optional record sep.

d. Display characters (see Table 6) Optional record sep.

e. Vnorm (see format below) Optional record sep.

f. Hnorm (see format below) Optional record sep.

g. Vzero (see format below) Optional record sep.

h. Hzero (upper) (see format below) Optional record sep.

i. Hzero (lower) (see format below) Optional record sep.

j. Reset Norm. Vzero (see format below) Optional record sep.

k. Reset Norm. Hzero (see format below) Optional record sep.

l. Optional End of File (EOF).

[4094 output]

4. Error code for norm. transmission (00-31) Optional error delimiter.

Normalization Format:

Normalization data is required if the actual voltage and time for each data point is desired. Unnormalized data values range from -32768 to +32767 regardless of any front panel setting. Normalization allows data values to be converted into voltages, and data point locations into time values. "Standard" normalization reflects the original front panel settings during signal acquisition. "Reset" normalization values have meaning after the front panel function RESET NUM is used. RESET NUM causes the zero time, zero voltage location to be changed on the display, thus requiring new normalization values. Standard and reset normalization sets exist for every waveform in memory. Vnorm, Hnorm, Vzero and Hzero are the most commonly used and important normalization parameters. The following paragraphs present portions of the normalization set in order of transmission.

1. Waveform validity - This number is used to determine if the waveform is valid. It is possible that the waveform data has resulted from a trigger VIEW display or is being transferred while in the trigger set-up mode (see relevant plug-in descriptions). This data does not reflect an actual measurement condition and is usually avoided. The waveform validity number makes it easy to avoid these undesirable conditions.

Waveform validity	Condition of Data
0	Data is a valid waveform
1	Data is derived from set-up mode
2	Data is derived from trigger VIEW
3	Data is derived from simultaneous trigger VIEW and set-up mode
6	Data is derived from the external trigger input while in trigger VIEW
7	Data is derived from simultaneous set-up mode, trigger VIEW, and external trigger input

Table 3

2. Sweep size index - A number which specifies the fraction of total memory occupied by the waveform. The 4094 requires this number to tie the

normalization information to the correct data points. If a normalization set is sent into the 4094 the sweep size index must be correctly specified in order to correctly normalize the data. Normally the sweep size index sent out by the 4094 is used when inputting to the 4094.

15872 pts./2^{SSI} = pts. in waveform.

Sweep size index	Fraction of total memory
0	ALL = 15872 pts.
1	1/2 = 7936 pts.
2	1/4 = 3968 pts.
3	1/8 = 1984 pts.
4	1/16 = 992 pts.
5	1/32 = 496 pts.

Table 4

3. Channel no. - An indication of which input channel and plug-in was used to acquire the waveform. This number is also given by the W command. Internal to the 4094, this number generates the 1A, 1B, 2A, 2B designators shown on the normal waveform display.

Channel no.	Input Location
0	Plug-in 1, Channel A
1	Plug-in 1, Channel B
2	Plug-in 2, Channel A
3	Plug-in 2, Channel B

Table 5

4. Display character no. - This number indicates the characters displayed along with the specified waveform. Normally the display character number sent out by the 4094 is used when normalization is sent into the 4094. However, under some conditions it may be desirable to blank off time and voltage units for a waveform which results from a computer calculation.

Display character no.	Characters on display
0	None of the conditions below
1	"R" shown to indicate Retain Ref. points
2	Blank time and voltage units
3	Combination of 1 and 2

Table 6

5. Vnorm - A number in the form x.xxxE+xx which is equal to the voltage between data point values (for example: +16842 to +16843) at the time the waveform was acquired. The letter "E" precedes the signed exponent value. The decimal point must be located as shown when Vnorm is sent into the 4094. Before using Vnorm to calculate a data point voltage Vzero must be taken into account. The calculation example on page 47 shows the correct usage of Vnorm and Vzero. Vnorm is related to the voltage range setting on the front panel.

$$\text{Vnorm} = \frac{\text{Voltage Range Setting}}{32000}$$

6. Hnorm - A number in the form x.xxxE+xx which is equal to the time between data points (time per point) on the specified waveform. The letter "E" precedes the signed exponent value. The decimal point must be located as shown when Hnorm is sent into the 4094. Before Hnorm is used to calculate the waveform time base Hzero should be taken into account. The calculation example on page 47 shows the correct usage of Hnorm and Hzero.

7. Vzero - The data value which represents the vertical location of zero volts (ground potential) for the chosen waveform. Vzero ranges from -32768 to +32767. All data point voltages on the 4094 display are with respect to ground regardless of their vertical positioning on the screen. Vzero must be subtracted from data point values to correct for the vertical location of ground potential. The calculation example on page 47 shows the correct usage of Vzero.

8. Hzero (upper), Hzero (lower) Hzero represents the location of the

trigger point (zero time) on the waveform. Through use of the plug-in trigger delay controls the trigger point (zero time) can be located to the left of the screen or at any point on the screen. Hzero ranges from -67,158,527 to +15859 and therefore is broken up into two numbers, upper and lower. The total Hzero results from the following operation:

(Hzero (upper)) x (65536) + Hzero (lower) = Total Hzero

Subtraction of the total Hzero from each data point number gives the correct relative location from the zero time trigger point. The calculation example on page 47 shows the correct usage of Hzero.

9. Reset Norm. Vzero - This number has a meaning similar to Vzero except that it pertains only to reset numerics. The RESET NUM function on the 4094 allows zero time, zero voltage to be moved to any point on a waveform. The resulting reset numerics (only seen while in RESET NUM) require additional reset normalization parameters to be preserved along with the standard normalization. Reset norm. Vzero ranges from -32768 to +32767 to give the location of zero voltage while using reset numerics.

10. Reset Norm. Hzero - This number is similar to Hzero except that it pertains only to reset numerics. The RESET NUM function allows zero time to be located at any displayed waveform data point. The resulting reset numerics (only seen while in RESET NUM) require additional reset normalization parameters to be preserved along with the standard normalization. Reset norm. Hzero ranges from +00000 to +15871.

Normalizing Example:

	00103.125E-08	1.000E-06	+04096	-00021	+50614	-20942	+14271
See description:	1234 5	6	7	8	8	9	10

The typical normalization set (above) is shown as a character string without record separator delimiters. Spaces can be used interchangably with + signs and leading zeros.

Time at a given data pt. = (Data point no. - Total Hzero) Hnorm

Voltage at a given data pt. = (Data point value - Vzero) Vnorm

Reset time numerics at a given data pt. = (Data point no. - Reset norm. Hzero) Hnorm

Reset voltage numerics at a given data pt. = (Data point value - Reset norm. Vzero) Vnorm

Assume that data point no. 1063 equals +00422, normalization set shown above is used.

Time at pt. 1063 = $(1063-(65536(-21)+50614))(1 \times 10^{-6})$

Voltage at pt. 1063 = $(422-4096)(3.125 \times 10^{-8})$

Reset time at pt. 1063 = $(1063-14271)(1 \times 10^{-6})$

Reset voltage at pt. 1063 = $(422+20942)(3.125 \times 10^{-8})$

Disk Recorder Operation

Command Format:

S, Drive No., Record No., Memory Section

(any non-numeric character can be used to separate numeric values)

Purpose:

Store displayed waveform on designated disk and record number.

Specifications:

1. Drive no. - 0 = single disk drive or left hand drive on dual disk recorder. 1 = right hand disk drive on dual disk recorder.
2. Record no. - The record no. (1-20) on which data is to be stored. Record 0 can be used to store on whichever record is displayed.
3. Memory section - Specifies the section of memory to be recorded onto disk. Q1 of memory will go to F1 on disk, etc.

Memory Section	Portion of Memory
0	ALL
1	Q1
2	Q2
3	Q3
4	Q4
5	H1
6	H2

Transmission Sequence:

[4094 input]

1. S, Drive no., Record no., Memory Section Optional command delimiter

[4094 output]

2. Error code for command and disk recorder (00-31) Optional error delimiter

Note: Before the error code is sent out by the 4094 the disk recorder STORE must be completed. The error code can be used as an indication that the STORE has been completed.

Command Format:

R, Drive No., Record No., Memory Section

(any non-numeric character can be used to separate numeric values)

Purpose:

Recall waveform data from the specified disk and record into the 4094 display memory.

Specifications:

1. Drive no. - 0 = single disk drive or left hand drive on dual disk recorder. 1 = right hand disk drive on dual disk recorder.
2. Record no. - Corresponds to the record no. (1-20) which is to be recalled into the 4094 memory. Record 0 can be used to recall whichever record is displayed.
3. Memory section - Specifies the section of memory to be filled by recalling from disk. F1 on disk will go into Q1 of memory, etc.

Memory Section	Portion of Memory
0	All
1	Q1
2	Q2
3	Q3
4	Q4
5	H1
6	H2

Transmission Sequence:

[4094 input]

1. R, Drive No., Record No., Memory Section Optional command delimiter

[4094 output]

2. Error code for command and disk recorder (00-31) Optional error delimiter

Note: Before the error code is sent out by the 4094 the disk recorder RECALL must be completed. The error code can be used as an indication that the RECALL has been completed.

Command Format:

U, Drive No., Record No., Memory Section

(any non-numeric character can be used to separate numeric values)

Purpose:

Unprotect specified record on disk recorder.

Specifications:

1. Drive no. - 0 = single disk drive or left hand drive on dual disk recorder. 1 = right hand drive on dual disk recorder.
2. Record no. - Record (1-20) to be unprotected. Record 0 can be used to unprotect whichever record is displayed.
3. Memory section - Record segment to be unprotected.

Memory Section	Record Segment
0	All
1	F1
2	F2
3	F3
4	F4
5	H1
6	H2

Transmission Sequence:

[4094 input]

1. U, Drive No., Record No., Memory Section Optional command delimiter

[4094 output]

2. Error code for command and disk recorder (00-31) Optional error delimiter

Note: Before the error code is sent out by the 4094 the disk recorder UNPROTECT must be completed. The error code can be used to indicate that the UNPROTECT is completed.

Command Format:

A, Drive No., Record No., Memory section

(any non-numeric character can be used to separate numeric values)

(Note: Computer Control must be turned on before command A can be used, see Transmission Sequence)

Purpose:

Initiate the disk recorder AUTOCYCLE mode of operation.

Specifications:

1. Drive no. - 0 = single disk drive or left hand drive on dual disk recorder. 1 = right hand drive on dual disk recorder.
2. Recorder no. - The record no. (1-20) on which AUTOCYCLE is started. Record 0 will start the AUTOCYCLE on whichever record is displayed. No protected records can exist between the starting record and record 20.
3. Memory section - Portion of memory in which the AUTOCYCLE recordings are to be made. Q1 of memory will go into F1 on disk, etc.

Memory Section	Portion of Memory
0	All
1	Q1
2	Q2
3	Q3
4	Q4
5	H1
6	H2

Transmission Sequence:

[4094 input]

1. Z1 Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

Z1 is used to turn on computer control. This is required before the autocycle command can be used. Z1 is covered under Advanced Interfacing Commands.

[4094 input]

3. A, Drive No., Record No., Memory Section Optional command delimiter

[4094 output]

4. Error code for command and disk recorder (00-31) Optional error delimiter

Note: AUTOCYCLE must be completed before the disk recorder error code is sent out. The error code can be used to indicate completion of AUTOCYCLE.

[4094 input]

5. ZØ Optional command delimiter.

[4094 output]

6. Error code for command (00-31) Optional error delimiter

ZØ is used to turn off computer control.

Waveform Acquisition

Command Format:

H, Mode, Plug-in No.

(any non-numeric character can be used to separate numeric values)

(Note: Computer Controls must be turned on before command H can be used, see Transmission Sequence)

Purpose:

The H command sets up the 4094 for waveform acquisition by running LIVE and HOLD NEXT.

Specifications:

1. Mode - Indicates the operation to be performed.

Mode	Plug-in Operation
0	Live/Hold Next and wait, command error code is output when plug-in goes into HOLD LAST
1	LIVE/HOLD NEXT, immediate output of command error code
2	Abort sweep, plug-in goes into HOLD LAST
3	LIVE

2. Plug-in No. - 0 = all plug-ins, 1 = plug-in on left, 2 = plug-in on right.

Transmission Sequence:

[4094 input]

1. Z1 Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

Z1 is used to turn on Computer Control. This is required before the H command can be used. Z1 is covered under Advanced Interfacing Commands.

[4094 input]

3. H, Mode, Plug-in No. Optional command delimiter.

[4094 output]

4. Error code for command (00-31) Optional error delimiter.

[4094 input]

5. ZØ Optional command delimiter

[4094 output]

6. Error code for command (00-31) Optional error delimiter

ZØ is used to turn off Computer Control.

Display Titling

Command format:

T, I/O, Title No.

(any non-numeric character can be used to separate numeric values)

Purpose:

The T command allows titles to be sent into or out of the 4094. In most cases, long titles can be input more easily through computer interfacing than by use of the disk program TITLE. A disk recorder is not necessary for computer titling.

Specifications:

1. I/O - Indicates the direction of title transfer.

I/O	Direction
0	4094 output
1	4094 input

2. Title No. - Specifies the title number to be transferred. The 4094 is able to hold a title for each quarter of memory.

Title No.	Where Title is Visible
1	Q1, H1,ALL
2	Q2, H2
3	Q3
4	Q4

Transmission Sequence:

[4094 input]

1. T, I/O, Title No. Optional command delimiter.

[4094 output]

2. Error code for command (00-31) Optional error delimiter.

[4094 input or output]

3. 32 character title Optional End of File delimiter.

[4094 output]

4. Error code for title (00-31) Optional error delimiter

It is important to note that any title sent into the 4094 must be exactly 32 characters long. This can only be accomplished reliably if formatted output statements are used by the computer. Nonformatted output statements may allow excess characters to be output. Delimiters count as output characters and should be eliminated if not desired as part of the title. Control characters which are normally non-printable ASCII characters are displayed as an appropriate ASCII character with an underline (for example: SOH = Control A = A).

If end of file delimiters are used, a title may contain fewer than 32 characters. It will, however, result in a premature end of file error.

Status

Command Format:

L, Status No.

Purpose:

The L command is used to determine whether a plug-in is in LIVE or HOLD LAST. This is commonly used to check for waveform acquisition after the 4094 is placed into LIVE/HOLD NEXT. L can also return information on the type of disk in each disk recorder.

Specifications:

1. Status No. - Specifies the information to be returned by the 4094.

Status No.	Status Returned
0	LIVE status: 0 = All plug-ins in HOLD LAST, 1 = At least one plug-in in LIVE
1	LIVE Status (as above), Drive 0 diskette status (0-4), Drive 1 diskette status (0-4), see table below

Diskette Status	Type of Diskette
0	Disk recorder is empty, no diskette
1	2090 diskette
2	4094 diskette
3	Program diskette, front panel execution type
4	Program diskette, computer interface execution type

Transmission Sequence:

[4094 input]

1. L, Status No. Optional command delimiter.

[4094 output]

2. Error code for command (00-31) Optional error delimiter.

[4094 output]

3. LIVE status (0 or 1) Optional record sep. Optional end of file.
   (command L,Ø results in transmission 3 only)

4. a. LIVE status (0 or 1) Optional record sep.
   b. Drive 0 diskette status (0-4) Optional record sep.
   c. Drive 1 diskette status (0-4) Optional record sep.
   d. Optional end of file delimiter.
   (command L,1 results in transmission 4 only)

Optional Delimiters/Control Characters

Command Format:

C, Address, Character

or

C, Address, Count, Character 1, Character 2, Character 3

(any non-numeric character can be used to separate numeric values)

Purpose:

The C command is used to set optional delimiters, optional control characters, and the RS-232C turn around time.

Specifications:

Table 7 shows the relationship between command addresses (not related to GPIB addresses) and the optional character to be set. Default characters are used by the 4094 unless new choices are specified. Each character in the C command is specified as a decimal number which is equivalent to the chosen ASCII character, see the ASCII chart on page 8.

For example:

CR = 0001101 = 13

LF = 0001010 = 10

$ = 0100100 = 36

Record separators, end of files, and error delimiters can have up to three characters specified by the count number. A count of 0 means that no delimiters is used. All remaining optional characters can have only one character specified thus a count is not necesary. To turn a character off, specify a character number from 128 to 255.

Address	Control Function	Default Character	Max. no. of of Characters
0	End of File (EOF) delimiter	no EOF	3
4	Record Separator delimiter	no record sep.	3
8	Error delimiter	Carrage Return Line Feed (CR/LF)	3
12	Abort RS-232C transmission	z	1
13	Command delimiter	Line Feed (LF)	1
14	Exponent character	E	1
15	RS-232C turn around time	0 msec.	1 number (000-255)
16	RS-232C XON	DC1 (Control Q)	1
17	RS-232C XOFF	DC3 (Control S)	1
18	Activate RS-232C transmission	SOH (Control A)	1
19	RS-232C address	DIP Switch address	1 number (000-127)

Table 7

Transmission Sequence:

[4094 input]

1. a. C, Address, Character Optional command delimiter.

or

b. C, Address, Count, Character 1, Character 2, Character 3 Optional command delimiter.

[4094 output]

2. Error code for command (00-31) Optional error delimiter.

Beep

Command Format:

B

Purpose:

Causes the 4094 to make one audio frequency beep.

Transmission sequence:

[4094 input]

1. B Optional command delimiter.

[4094 output]

2. Error code for command (00-31) Optional error delimiter.

RS-232C Deactivate

Command Format:

Q

Purpose:

The Q command is used only in RS-232C interfacing to deactivate the interface. It has an effect opposite of the activation control character and RS-232C address shown in the RS-232C OVERVIEW. After use of the Q command the RS-232C interface must be reactivated before additional RS-232C communications can take place. Command Q will deactivate all 4094's chained together on a single RS-232C line.

Transmission Sequence:

[4094 input]

1. Q Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

Error Code Numbers

00 - no error

20 - mixed data error, see Note 1

21 - aborted

22 - no command in input string

23 - wrong parameter in input string

24 - parameter in input string too large

25 - waveform parameter goes past end of waveform

26 - D command; mode number incorrect

29 - no disk or not a data disk

30 - premature End Of File (EOF)

31 - no End Of File (EOF) on input stream

Disk recorder error numbers can be found in the appropriate disk recorder section of this manual.

Note 1: A mixed data error indicates that the 4094 display memory contains waveforms which are missing data points due to newly acquired waveforms. For instance, a waveform put into ALL would be partially destroyed by a later waveform put into H2. The mixed data error alerts the programmer to the fact that normalization data for the ALL waveform does not take into account the missing points.

ADVANCED INTERFACING COMMANDS

The advanced 4094 I/O commands require a deeper understanding of internal 4094 operation than the basic interfacing commands. Operations included in the advanced I/O commands are:

1. Computer Control ON/OFF
2. Reading and setting plug-in front panel
3. Reading and setting mainframe front panel
4. GPIB/Plotter port I/O
5. MODEM/COMPUTER and PLOTTER port parameters

Advanced commands are similar in structure to the basic commands. The advanced commands allow the programmer to influence fundamental 4094 front panel actions and therefore must be used with care.

Computer Control ON/OFF

Command Format:

Z Mode

Purpose:

The Z command turns on/off the 4094 computer control mode. Computer control refers to an internal mode of operation in which the I/O processor (which normally runs the disk recorders, interfaces, digital plotter, and disk programs) takes charge of the internal 4094 procedures and prevents external manipulation of front panel functions. When the 4094 is in computer control the characters CC are shown on the display screen. Computer control must be turned on for the advanced front panel controls and for the basic command A which turns on AUTOCYCLE. When computer control is turned off the 4094 reverts back to normal operation with standard, manually manipulated front panel controls.

Specifications:

1. Mode - A number to indicate whether computer control is to be turned on or off.

   0 = computer control off

   1 = computer control on

Transmission Sequence:

[4094 input]

1. Z Mode Optional command delimiter.

[4094 output]

2. Error code for command (CO-31) Optional error delimiter.

Plug-in Front Panel Manipulation

Command Format:

To input to 4094: P, Address, Setting, Mask

To output from 4094: P, Address

Purpose:

The P command allows plug-in front panel controls to be changed via computer commands and permits actual front panel switch settings to be read. If front panel controls are to be changed away from the actual switch settings Computer Control must be turned on. Even while Computer Control is on and new settings are being used, the actual front panel switch settings can be read. Through use of the P command the actual front panel settings can be read at any time without turning on Computer Control. The P command also allows the SWEEP average count (no. of sweeps taken while in AVERAGE) to be read and allows trigger delays to be set or read.

Specifications:

1. Address - A number (0-41) which defines the quantity to be read or changed. See Tables 8 and 9.
2. Setting - A number which represents the control to be turned on or the actual numeric value to be sent into the 4094. Table 8 shows a variety of front panel controls and the settings which will cause them to be actuated. A group of settings with a single address can be actuated with a single P command by adding up the corresponding settings. Note that quite a few front panel controls are represented in negative logic (such as "CH A OFF") so that a zero placed in that position will actually cause the control to be asserted. The Mask number makes it possible to access only a specific control function. Table 9 shows

settings which directly place numeric values into internal 4094 control locations. Masks are not needed for Table 9.

3. Mask - A number which indicates the control to be changed. Settings made using Table 8 are generally made with a mask equal to the setting. Inputting a new setting without a mask will generate multiple changes as other controls located at the same address are zeroed. As with settings, a single mask number can access several controls at the same address by summing the mask numbers. To assert a negative logic control (for example, turn CH B on) a setting of 0 must be combined with a suitable mask number.

   CH B on = P, 2, 0, 1 (for plug-in 1)

   Masks are not needed with addresses 4-9 and 36-41.

Transmission Sequence:

To read plug-in setting (Computer Control on or off),

[4094 input]

1. P, Address Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

[4094 output]

3. Setting number (0-65535) Optional record sep.

[4094 output]

4. Optional End of File delimiter

To input plug-in settings (Computer Control must be on),

[4094 input]

1. Z1 Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

[4094 input]

3. P, Address, Setting, Mask Optional command delimiter

[4094 output]

4. Error code for command (00-31) Optional error delimiter

Computer Control (Z1) must remain on as long as the 4094 is expected to ignore actual front panel settings and perform based on the new settings.

ADDRESS For PLUG-IN NUMBER		I/O DIRECTION	SETTINGS AND MASK															
#1	#2		1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192	16384	32768
0	32	Read only. See Note 1.	ChB off	not slav trig	not neg slpe	not B delay pddle left	not used	not B Ret Ref	not A Ret Ref	not B delay pddle right	Enter delay set'g	not Hold Next	not A delay pddle left	not Hold Last	not A delay pddle right	do not use	not pos slpe	ChA off
1	33		ChA voltage range Read only. A1 / A2 / A3 / A4				ChA X10 Prbe	ChB voltage range Read only. B1 / B2 / B3 / B4				ChB X10 Prbe	Auto Trig	Time Per Point T1 / T2 / T3 / T4 / T5				
2	34	Read/Write. See Note 2.	Same as for Addresses 0 and 32															
3	35		Same as for Addresses 1 and 33															

NOTE 1: Read only to see actual switch positions.
NOTE 2: Read/Write to access settings used by 4094. Computer control must be ON to set a value.
ADDITIONAL NOTE: Tables 10 and 11 contain clarifications of A1-A4, B1-B4, and T1-T4.

TABLE 8

ADDRESS For PLUG-IN NUMBER		QUANTITY	SETTING
#1	#2		
4	36	Sweep average count	0 through 21800 (Read only)
5	37	Not used	
6	38	Channel B Trigger Delay (low order)	See Notes 1, 2, and 3
7	39	Channel B Trigger Delay (high order)	See Notes 1, 2, and 3
8	40	Channel A Trigger Delay (low order)	See Notes 1, 2, and 3
9	41	Channel A Trigger Delay (high order)	See Notes 1, 2, and 3

TABLE 9

NOTE 1: Use the following equations to compute trigger delay settings.

I. To position the trigger at any point on the screen:

a. Trigger Delay (high order) = 0

b. Trigger Delay (low order) = $\dfrac{\left|\text{Trigger Pt. Time}\right|}{\text{Time Per Point}}$ = No. of data points to the right

II. To position the trigger off the display screen to the left:

a. If $\frac{|\text{Delay Trigger Time}|}{\text{Time Per Point}} \leq 65536$, then

Trigger Delay (high order) = 65536

Trigger Delay (low order) = $\frac{|\text{Delay Trigger Time}|}{\text{Time Per Point}} - 65536$

b. If $\frac{|\text{Delay Trigger Time}|}{\text{Time Per Point}} > 65536$, then

divide $\frac{|\text{Delay Trigger Time}|}{\text{Time Per Point}}$ by 65536.

Separate the answer into whole and fractional portions,
(for example: 1.6249 ⟶ 1 and 0.6249).
Whole portion - 65536 = Trigger delay (high order)
(Frac. portion x 65536) - 65536 = Trigger delay (low order)

NOTE 2: The decimal arithmetic given in Note 1, on the previous page, is one way of correctly working with 32 bit 2's compliment binary numbers. Trigger delay values which lie on the screen are positive 32 bit numbers. Trigger delay values which lie off the display screen to the left are negative 32 bit numbers (2's compliment). Each 32 bit number is separated into two 16 bit groups; high order, low order. Programmers familiar with manipulation of 32 bit binary numbers will find it unnecessary to follow the procedure shown in Note 1.

NOTE 3: In order to set trigger delays it is necessary to first turn on the "Enter delay set'g" shown on Table 8, addresses 2 or 34, setting 256. After the trigger delay setting is made the "Enter delay set'g" should be turned off by using a setting of 0 and a mask of 256.

Voltage Range	A1/B1	A2/B2	A3/B3	A4/B4
±100mV	1	1	0	0
±200mV	1	1	1	0
±400mV	0	1	0	1
± 1V	0	1	0	0
± 2V	0	1	1	0
± 4V	1	0	0	1
±10V	1	0	0	0
±20V	1	0	1	0
±40V	0	0	0	1

Note: Front panel voltage range settings represented by A1-A4 and B1-B4 should only be read. New settings cannot be made via computer interfaces.

Table 10

Time per Point						
Model No. 4562	4851	T1	T2	T3	T4	T5
0.5us	10us	1	1	1	1	1
1	20	0	1	1	1	1
2	50	1	0	1	1	1
5	100	0	0	1	1	1
10	200	1	1	0	1	1
20	500	0	1	0	1	1
50	1ms	1	0	0	1	1
100	2	0	0	0	1	1
200	5	1	1	1	0	1
500	10	0	1	1	0	1
1ms	20	1	0	1	0	1
2	50	0	0	1	0	1
5	100	1	1	0	0	1
10	200	0	1	0	0	1
20	500	1	0	0	0	1
50	1sec.	0	0	0	0	1
100	2	1	1	1	1	0
200	5	0	1	1	1	0
500	10	1	0	1	1	0
1sec.	20	0	0	1	1	0
2	50	1	1	0	1	0
5	100	0	1	0	1	0
10	200	1	0	0	1	0
20	500	0	0	0	1	0
50	1000	1	1	1	0	0
100	2000	0	1	1	0	0
200	5000	1	0	1	0	0

Table 11

Mainframe Front Panel Manipulation

Command Format:

To input to 4094: M, Address, Setting, Mask

To output from 4094: M, Address

Purpose:

The M Command allows mainframe front panel controls to be changed via computer commands and permits actual front panel switch settings to be read. If front panel controls are to be changed away from the actual switch settings Computer Control must be turned on. Even while Computer Control is on and new settings are being used, the actual front panel switch settings can be read. Through use of the M command the actual front panel settings can be read at any time without turning on Computer Control. The M command also makes it possible to read or set horizontal and vertical cursor positions while in XY or YT.

Specifications:

1. Address - A number (0-15) which defines the quantity to be read or changed. See Tables 12 and 13.
2. Setting - A number which represents the control to be turned on or the actual numeric value to be sent into the 4094. Table 12 shows a variety of front panel controls and the settings which will cause them to be actuated. A group of non mutually exclusive settings at a single address can be actuated with a single M command by adding up the settings. Settings at address 6 are mutually exclusive. Some settings at address 8 are non mutually exclusive. Since nearly all mainframe settings are mutually exclusive a single setting without a mask is generally used. Turning on multiple settings which cannot normally

be set on the front panel (for example, x16 and x256 together) will lead to unpredictable results. Table 13 shows settings which directly place numeric values into the 4094 to affect cursor locations.

3. Mask - A number which indicates the control to be changed. Mask numbers are only necessary when settings at address 8 are made. All other groups of settings are mutually exclusive or read only and thus mask numbers should not be used. Use of mask numbers at addresses containing mutually exclusive settings (such as 6, 7, 9, 10, 11) will give unpredictable results.

Transmission Sequence:

To read mainframe settings (Computer Control on or off),

[4094 input]

1. M, Address Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

[4094 output]

3. Setting number (0-65535) Optional record sep.

[4094 output]

4. Optional End Of File delimiter

To input mainframe setting (Computer Control must be on),

[4094 input]

1. Z1 Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

[4094 input]

3. M, Address, Setting, Mask Optional command delimiter

[4094 output]

4. Error code for command (00-31) Optional error delimiter

Computer Control (Z1) must remain on as long as the 4094 mainframe is expected to ignore actual front panel settings and perform based on the new settings.

ADDRESS	I/O DIRECTION	FUNCTION	SETTINGS AND MASK								
			1	2	4	8	16	32	64	128	256
0	Read only to determine actual front panel switch locations	Vertical Expansion	OFF	X2	X4	X8	X16	X32	X64	X128	X256
1		Horizontal Expansion	OFF	X2	X4	X8	X16	X32	X64	X128	X256
2		Cursor Controls, Execute	Crsr ◄	Crsr ►	Crsr ▲	Crsr ▼	Exec.	Y/T	Autocntr	Zero	
3		Not Used									
4		Function Switch	Prgm	Invert	Sub	Data Move	Reset	Grid	Pen		
5		Memory Switch	Q1	Q3	H1	All	H2	Q2	Q4		
6	Read/Write to influence scope behavior - Computer Control must be turned ON	Vertical Expansion	OFF	X2	X4	X8	X16	X32	X64	X128	X256
7		Horizontal Expansion	OFF	X2	X4	X8	X16	X32	X64	X128	X256
8		Cursor Controls, Execute	Do not use (Cursor position keys) See Table 13.				Exec.	Y/T	Autocntr	Zero	
9		Not Used									
10		Function Switch	Prgm	Invert	Sub	Data Move	Reset	Grid	Pen		
11		Memory Switch	Q1	Q3	H1	All	H2	Q2	Q4		

NOTE: Mask numbers need only be used when accessing address 8.

TABLE 12

READ/WRITE CURSOR POSITIONS		
ADDRESS	CURSOR	SETTING
#12	X/Y Vert. Cursor	32768 thru 65535 (for -32768 thru -1), 0 thru 32767
#13	X/Y Hor. Cursor	32768 thru 65535 (for -32768 thru -1), 0 thru 32767
#14	Y/T Vert. Cursor	49664 thru 65535 (0 + 49664 thru 15871 + 49664)
#15	Y/T Hor. Cursor	32768 thru 65535 (for -32768 thru -1), 0 thru 32767
NOTE: Negative settings for addresses 12,13, and 15 must have 65536 added to them. Settings for address 14 must have 49664 added to them.		

TABLE 13

GPIB/PLOTTER Port I/O

Command Format:

J

Purpose:

The J command puts the 4094 into a unique mode of operation in which the 4094 acts as a GPIB/RS-232C translator. Normal GPIB communications will be passed through the 4094 and will be sent out the PLOTTER port. The GPIB transmission speed will be held down to equal the plotter port baud rate. Switch 5 (see pg. 21) allows two plotter baud rates to be set: OPEN = Baud rate set on Switches 1-4, closed = 2400 baud. The K command allows additional baud rates and RS-232C parameters to be selected. The PLOTTER port will have the same parity and number of stop bits as set for the RS-232C MODEM/COMPUTER port unless changed by the K command. The preprogrammed digital plotters offered by Nicolet modify the baud rate, parity, and stop bits during use therefore it is safest to make necessary settings with the K command before using the J command. The 4094 GPIB/RS-232C translation is bidirectional. After issuing the J command into the GPIB port, transmissions coming into the PLOTTER port will be relayed out the GPIB. PLOTTER port to GPIB communications will procede at the baud rate selected, the GPIB controller must be able to keep pace. This is not a genuine restriction since it only requires a controller to run at approximately 2000 bytes/sec. (at maximum). Slower transmission speeds can be chosen by selecting a slower plotter port baud rate. The GPIB/PLOTTER port interconnection can be terminated by issuing a Device Clear, Selected Device Clear, or Interface Clear from the GPIB controller. Note that initiation and termination of this mode of operation must come

from the GPIB controller.

The PLOTTER port is configured as data communications equipment and is therefore directly compatible with printers, terminals, digital plotters, and computers configured as data terminal equipment. The primary difference between data terminal equipment and data communications equipment is the location of the transmit and receive lines.

Data terminal equip. -	line 2 = transmit
	line 3 = receive
Data communications equip. -	line 2 = receive
	line 3 = transmit

A modem connected to the plotter port will require lines 2 and 3 to be crossed since it is also data communications equipment. Handshaking lines may need to be hardwired together (see uses of the null modem board in the RS-232C Start-up) to correctly connect two pieces of data communications equipment together.

There are many possible uses of this unique GPIB/RS-232C translator. The most obvious is the ability to directly communicate between a GPIB compatible computer and a RS-232C compatible digital plotter. However this mode of operation can be considered to be a general purpose GPIB/RS-232C converter. Any GPIB controller is capable of communicating with a variety of RS-232C devices.

Transmission Sequence:

[GPIB 4094 input]

1. J Optional command delimiter

[GPIB 4094 output]

2. Error code for command (00-31) Optional error delimiter

Bidirectional GPIB/Plotter port communications are now possible [GPIB 4094 input]

3. Device Clear, Selected Device Clear, or Interface Clear. A computer manual must be consulted to determine the correct command to issue the necessary clear.

MODEM/COMPUTER and PLOTTER Port Parameters

Command Format:

K, Port, Mode, Baud Rate No.

Purpose:

The K command is used to vary the parameters affecting the RS-232C MODEM/COMPUTER port and the RS-232C PLOTTER port. Baud rate, parity on/off, parity odd/even, and number of stop bits can all be set using the K command. The 8 segment DIP switch discussed starting on page 21 is another way to set these parameters. The PLOTTER port and the MODEM/COMPUTER port will operate according to the DIP switch settings unless modified by the K command. When using the GPIB/PLOTTER port interconnection (see command J) it is best to first use the K command to ensure that the PLOTTER port is set up as needed. The preprogrammed digital plotters offered by Nicolet modify the plotter port baud rate, parity, and stop bits during use and therefore it is safest to make necessary settings with the K command before using the J command.

Specifications:

1. Port - A number corresponding to the RS-232C port to be modified.

   0 = MODEM/COMPUTER port

   1 = PLOTTER port

2. Mode - A number used to specify parity, number of stop bits and corresponding character length. The mode numbers given below be added up to create the total setting.

Mode	No. of Stop Bits
0	1 1/2
64	2
128	1

Mode	Parity
0	None
32	Even
48	Odd

Mode	Character Length
0	5 bits
1	6 bits
2	7 bits
3	8 bits

Examples:

a. 1 stop bit, no parity = 128 + 0 + 3

b. 1 stop bit, odd parity = 128 + 48 + 2

c. 1 stop bit, even parity = 128 + 32 + 2

d. 2 stop bit, no parity = 64 + 0 + 3

3. Baud Rate No. - A number which specifies the baud rate (bits per second) of the transmissions.

Baud Rate No.	Baud Rate
1232	30
417	1200
52	9600
1592	110
1441	150
1163	450
1128	600
278	1800
250	2000
208	2400
139	3600
104	4800
69	7200
35	14400
26	19200
13	38400

Transmission Sequence:

[4094 input]

1. K, Port, Mode, Baud Rate No. Optional command delimiter

[4094 output]

2. Error code for command (00-31) Optional error delimiter

MP MASTER
MA29621